Distributed Energy Neural Network Integration System (DENNIS^{TM}) Quarterly Review

Orion Engineering Corporation

By:

Tom Regan and Herbert Sinnock

Madison,WI

July 9, 2002

NREL Technical Monitor: Holly Thomas

How Can Distributed Generation Get Full-Value Pricing?

- Avoided cost and net metering models are not viable for providing the first cost recovery rates needed to make distributed resources economical for household and small commercial applications.

- A solution to economically integrate distributed resources onto grid is needed. This solution should capture the full-value of the distributed resource.

- Solution will need to be adaptable, knowing when to sell and when to store energy (if site has ability).

- Solution will also need capacity to aggregate small blocks of power production into blocks large enough to make utility contracts.

2

Distributed Energy Neural Network Integration System (DENNIS^{TM})

- Distributed generation and storage systems need an adaptive mechanism that can predict the site specific energy generation capacity and power consumption.
- DENNIS^{TM} is optimization system that uses neural networks and fuzzy logic to determine where, when and which distributed generation resources are utilized.
- Solution predicts and meets demand of a particular user instead of curtailing that user's demand.
- Our system is now capable of optimizing to a single user or with application to a larger group of users coming in Year II. Year II and III expand this aspect of development to a "neighborhood controller".

Program Goals (Overall)

- Prototype, test and evaluate the system utilizing the facilities at the University of Massachusetts Lowell (UML) Center for Energy Conversion (CEC).

- Develop an economic model/analysis of the potential impact of our method for aggregating and managing distributed power.

- Deploy units to customer sites in two phases. First phase provides geographic dispersal during debugging and analysis. Second phase will be a beta product release.

- Establish industrial contacts and relationships to allow effective transfer of product into residential and business sectors.

- Inform and demonstrate to the electric power community the potential of a new business in generation communities.

Year One Program Tasks

Task 1 – Data Reduction and Analysis (Completed)

Task 2 – Power Electronics (Completed)

Task 3 – Fuel Cell Characterization and Integration (Completed)

Task 4 – Power Quality Study (Completed)

Task 5 – Pattern Database & Pattern Recognition (Completed)

Task 6 – Control Law Generator (Completed)

Task 7 – Preliminary Economic Analysis and Market Assessment (Completed)

YEAR ONE GOALS – Make infrastructure investments, develop neural network systems, and validate savings potentials.

How Did the Proposed DENNIS™ System Work?

- A Neural Pattern Database monitors and learns load, weather, price and available power data streams.

- Incoming signals were compared with patterns stored in Neural Pattern Database to select appropriate operating conditions.

- Optimization algorithm selects control strategy for power storage, power export/import and generation dispatch.

Our year one experience found that this strategy was not the most effective method possible.

How Does the Latest Version of DENNIS^{TM} Work?

- Neural network performs real time decision making

- Linear programming-based Optimizer system creates training sets using past data

- Network is continually retrained with newer data

Task 5 – Pattern Database Development

- Tested ARTMAP topology with weather data from UML
- Achieved 80% correct prediction using 1 month of data for training and testing
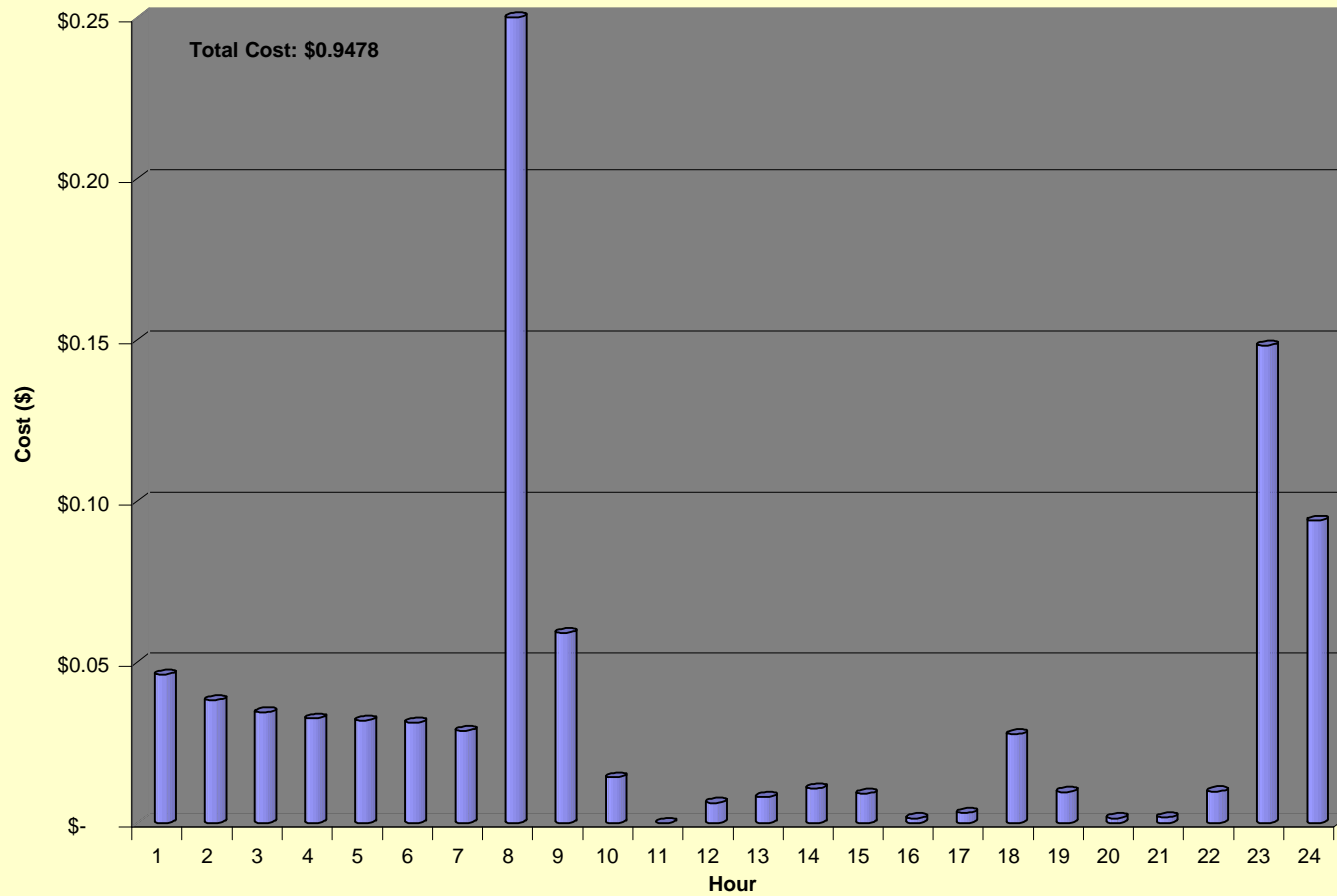

8
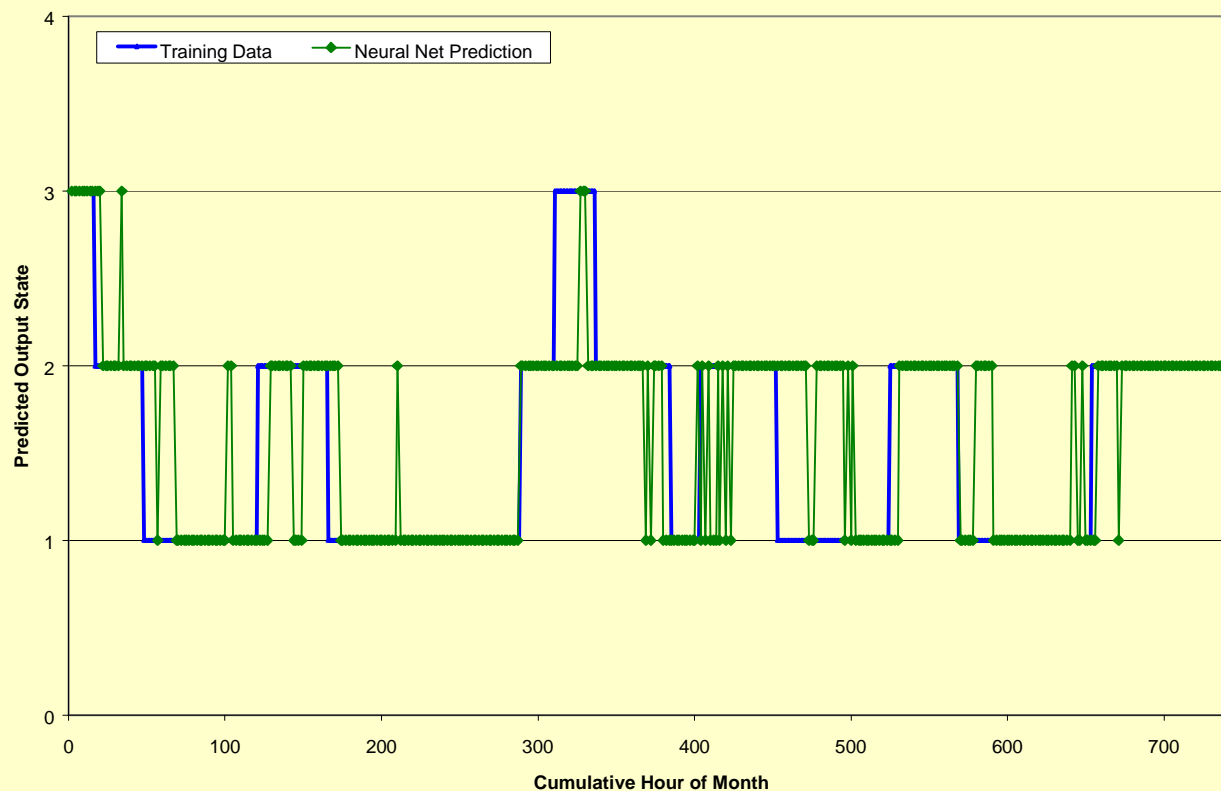
Task 6 – Control Law Generator

- Developed system of hourly cost and constraint equations

- Developed algorithm to solve complete set of constraint equations over 24 hours through linear optimization and iteration

- Compared performance to default pricing and systems with charge control

Rainy Day with Standard Storage
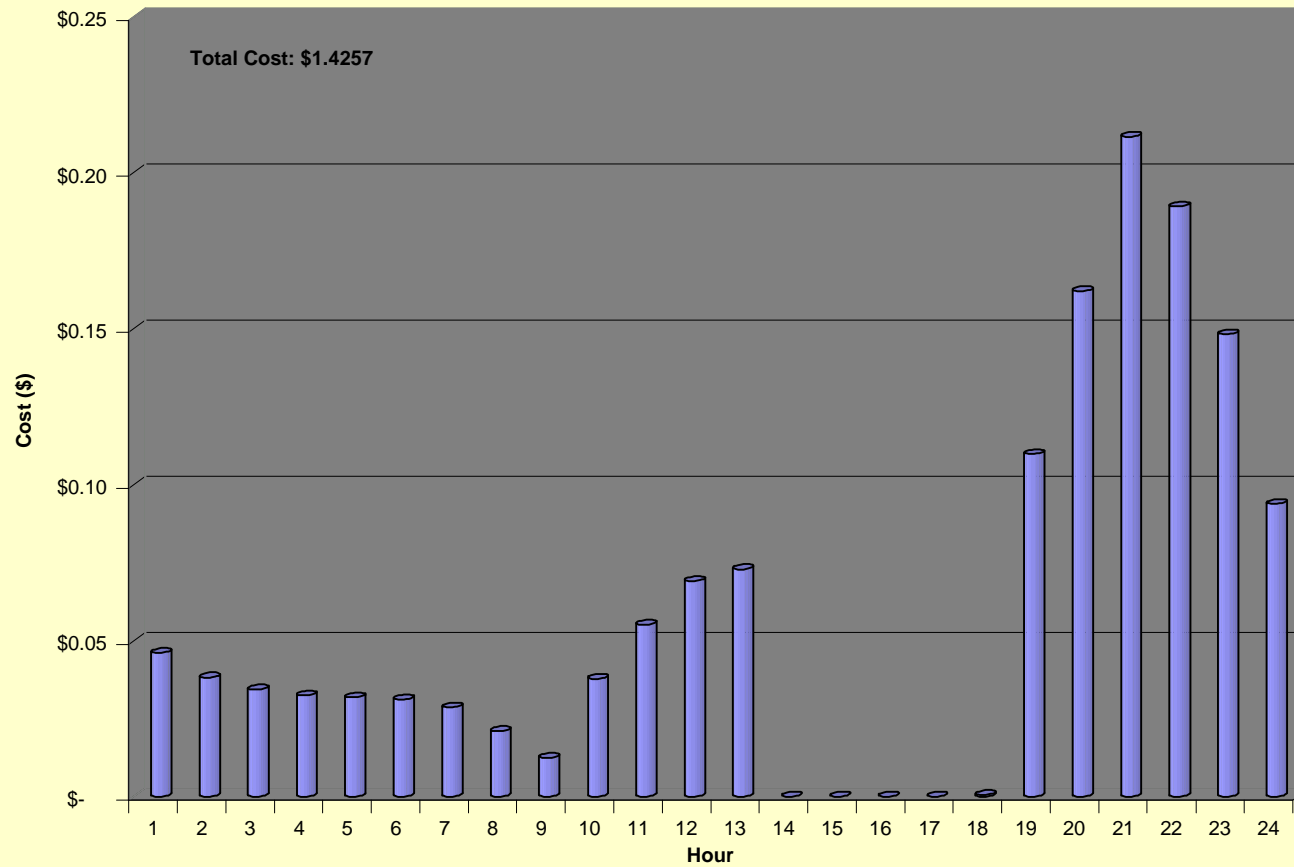
Rainy Day with DENNIS

Comparison of DENNIS™ System to Charge Controlled System

System	Case A – Sunny	Case B – Rainy	Total
Default – No Storage	$1.3323	$1.6092	$2.9415
Storage – Charge Control	$0.6837	$1.4257	$2.1094
Storage – Optimized	$0.5969	$0.9478	$1.5447

Task 7 – Preliminary Economic Analysis and Market Assessment

- DENNIS^{TM} beats avoided cost by up to 135%
  - On average it provides a savings of 115% for a photovoltaic installation (compared to only 60% for net metering)
  - On average by 60%for hydrocarbon
  - based on a house using approximately 20 kWh and generating 18-28kWh per day with 4kWh of storage available

- DENNIS^{TM} utility revenue is **$221** / customer-year

Year One Project Summary

At the end of Year One, the following activities were completed:

- Facilities upgrades at UMLCEC.

  – Fuel Cell logic modeled and characterized.

- Development of the neural network algorithms.

- Economic models demonstrating that DENNIS is a cost effective solution for distributed generation systems.

- Completing Year I sets the stage for field testing and debugging in Year II.

  – We are now moving away from our algorithm development to a hardware and code development program.

Option Year I Program

- During Option Year 1, OEC plans to advance DENNIS^{TM} from the design and prototype development achieved during the Base Year to installing and debugging the prototype system.

- This also marks the beginning of OEC's technology deployment and demonstration plan for the DENNIS^{TM} system.

  – We are currently working with industrial and government partners to construct additional distributed generation capacity on or near the UML campus.

  – This extensive distributed generation capacity will become a test and demonstration site for DENNIS^{TM} and similar systems from our industrial partners.

Option Year II Program Tasks

- **Task 8 - Control Site Development and Monitoring**
  - Enable real-time signaling and develop performance benchmarks for prototype controllers

- **Task 9 - External Site Deployment and Monitoring**
  - will remotely distribute DENNIS^{TM} controllers and gather performance data

- **Task 10 - Data Reduction and Economic Analysis**
  - Reduce and analyze data from remote sites

- **Task 11 - Utility Integration and Market Development**
  - work to transition technology to DISCO/EMCO entities

- **Task 12 - Neighborhood Controller Tech. Assessment**
  - develop central controller for lager blocks of users

Summary of Progress to Date

- We have completed the Year One program
  - Facility upgrades have been completed.
  - Neural networks and fuzzy logic algorithms development completed!
  - Economic model provides for 15 year payback for PV Systems (6%ROI)
- Option Year One tasks have been initiated
  - External controller site selection is underway.
  - Code translation in progress.
  - Linux based controller production underway.